Research FOR FARMERS

FALL—1960

CANADA DEPARTMENT OF AGRICULTURE

Research FOR FARMERS

CANADA DEPARTMENT OF AGRICULTURE
Ottawa, Ontario

HON. DOUGLAS S. HARKNESS — *Minister*

S. C. BARRY — *Deputy Minister*

NOTES AND COMMENTS

It doesn't often happen but once in a while a piece of research is actually hampered by its own success. A case in point is that of wireworm control in southwestern Ontario, as reported by Mr. Begg in this issue. At the Harrow station they found that some of the new chlorinated hydrocarbon insecticides used either as seed treatments, planting-water treatments or broadcast over the soil, virtually eliminated the wireworms. So effective, indeed, was the treatment that further studies of the pest are severely hampered for lack of wireworms, following widespread adoption of the recommended control measures. The researchers are keeping themselves in business by maintaining an artificially infested study plot where the pest can be held under observation so that any evidence of resistance to the prescribed insecticides may be detected in good time.

* * *

The worm in the apple has long been a matter of concern but never more so than in the Okanagan Valley orchards where today the codling moth is a major threat to the apple industry. For a variety of reasons, spray treatments fail to give adequate control but science is trotting out a new weapon that holds interesting promise. Adapting a technique that has proved effective elsewhere against other pests, entomologists at Summerland are using radiation to sterilize male codling moths. These are later released and when they mate the females lay infertile eggs that will not hatch. As Dr. Marshall relates in the article, "Orchard Warfare", in this number, it is theoretically possible to eliminate the species entirely through repeated releases of these sterile males. Should this be the happy result, the savings to growers and the general public would be tremendous.

* * *

Amid growing concern for the public welfare in the face of increasing use of pesticides, one fact must be kept in mind. Farmers do not use these chemicals because they want to but only because they will control food-destroying pests where other methods have failed. As new chemicals are developed, every consideration is given to the possible dangers of harmful residues. But if it is to have any value to the farmer, the product must do its job.

* * *

Erratum: With reference to the article: "Control of the Onion Maggot in B.C." in the Summer, 1960 issue of *Research for Farmers*, the caption for the cut at the bottom of page 4 should have read in the parenthesis "(right to left)" instead of "(left to right)".

FALL — 1960

Vol. 5 **No. 4**

"*Research for Farmers*" is published quarterly by the Canada Department of Agriculture. Its purpose is to help keep extension workers informed of developments in research and experimentation as carried on by the various units of the Department.

Contributions should be addressed to the Secretary, Editorial Board, Information Division, Canada Department of Agriculture, Ottawa.

Cover *Photo*—Dr. F. J. Svejda, Genetics and Plant Breeding Research Institute, Ottawa, preparing field pea seeds for x-irradiation under the x-ray machine.

(See story, page 3.)

X-irradiation

What Can It Possibly Mean To the Farmer

Preparing pea seeds for x-irradiation (see Cover Photo story on opposite page).

Iris L. Craig AND *Beatrice E. Murray*

NUCLEAR energy is of positive benefit to the farmer and finds constructive expression in the fields of theoretical and practical research. Ionizing radiations such as beta and gamma rays, radioactive substances and x-rays are known to induce changes in a plant's characteristics, not expressed in the parental stock, that are transmitted from one generation to the next. These changes are known as mutations.

Mutations occur spontaneously in nature and are the changes which, when acted upon by natural selection, result in evolution. Early agriculturists made use of these spontaneous changes and introduced new varieties by selecting plants with more vigorous growth, more disease resistance or greater seed production. The modern plant breeder likewise takes advantage of these mutations in his breeding program and, by hybridization and selection, attempts to produce varieties incorporating new characteristics and the best features of existing varieties.

Nature is not in a hurry and spontaneous mutations of a practical value are rare. The plant breeder attempts to accelerate the process by inducing mutations and this is where x-irradiation comes into use. X-irradiation probably does not create any new characteristics in a plant; it only speeds up the production of those that occur spontaneously.

Dr. Murray is an irradiation specialist with the Genetics and Plant Breeding Research Institute, Ottawa and Miss Craig is her assistant.

In the Genetics and Plant Breeding Research Institute at Ottawa, a low-growing mutant tomato has been induced by x-rays. This may be of agronomic value for close planting, a practice which is now coming into common use. Exposure of field peas to low dosages of x-irradiation appears to have produced plants that flowered earlier, grew taller and produced more pods and seeds per plant. A yield test conducted for two successive years showed an average increase of 27 per cent in the third and fourth generations.

X-irradiation has been effective in creating a great variety of distinctive leaf and flower changes in plants such as the African violet, carnation, petunia, snapdragon, phlox, tulip, etc.

Although a specific type of mutation cannot be produced at will, it has been proved that a given number of mutations will be produced by a specified amount of x-irradiation. This number of mutations depends upon the total dose of x-irradiation regardless of whether it is administered at a low rate over a long period or at a concentrated rate in a short period. The critical factor is the amount required. The amount of x-irradiation varies from one species to another and even between varieties of the same species. It also varies with the part of the plant being x-irradiated and with the physiological condition of that part. Dry seeds, for example, require much higher doses of x-irradiation than germinated seedlings or other vegetative parts.

Since the conditions of the plant and the environment have a definite effect on x-irradiation sensitivity, it is evident that such factors as temperature, moisture content, age, vigor, and treatment before and after x-irradiation all have to be considered. The objective is to administer a dose high enough to cause as many mutations as possible without too seriously impairing the germination and growth, or fertility of the plant. The greater our knowledge of these factors, the more efficiently we can use this important tool.

We have carried out an extensive program to determine the effect of x-irradiation on alfalfa. In this plant the basic set of eight chromosomes is repeated four times. Such a duplication of genetic material places this plant in a complex genetic system called polyploidy. Many important crops such as wheat, a number of grasses, oats, white clover as well as alfalfa, are polyploids. The program on alfalfa is an attempt to understand how x-irradiation affects this genetic system.

Our first problem was to ascertain the most effective means of using x-irradiation on alfalfa. Seeds, vegetative cuttings and pollen were exposed and the progeny examined, in greenhouse and field trials, for changes in flower color, pod formation, leaf size and shape or any deviation from normal behaviour. X-irradiated pollen, applied to the stigmas of vigorously growing male-sterile plants proved to be the most effective means of inducing variations. This

Dr. D. R. Sampson, Genetics and Plant Breeding Research Institute, examining a normal tomato plant (left) and an x-irradiated short-growing, high-yielding mutant (right).

program shows promise of helping us to understand the problems inherent in a polyploid crop so that we can reach out into the practical field by endeavoring to improve our present polyploid varieties or finding ways of developing new ones.

X-irradiation is a very effective tool for chromosome engineering. An outstanding recent example is the transfer of leaf-rust resistance to wheat from a related wild grass. This was engineered by the transfer to a wheat chromosome of a small segment, carrying rust resistance, from one chromosome of the wild species. Another example is the breaking of a linkage group in oats that tied resistance to crown rust and susceptibility to Helminthosporium blight so that they always appeared together in the progeny. This separation is a step forward in the eventual control of these diseases. The mapping or the location of genetic traits on the chromosomes and the breaking up of chromosome groups to facilitate the crossing of related species, etc., are all constructive uses of x-irradiation.

New varieties are essential to increase productivity, widen adaptability and aid in the control of newly important disease and insect pests. While x-irradiation is being used to induce variation and broaden the scope of material available for the plant breeder, it would be presumptuous to over-emphasize the practical importance of radiation research. Until we understand more about the actual effects of radiations and can efficiently control or direct them, the practical applications in spite of the record, are debatable. Although the frequency of mutations is increased by x-irradiation only about one in every 800 is of practical value. Moreover, in order to select the desired mutant, refined techniques for screening large numbers of plants are essential and these techniques are not always easy to develop. The required population size is too large for greenhouse or growth chamber experiments and quantitative characters such as size, vigor, and yield, are particularly difficult to work with when they are affected by environment.

On the other hand it would be a mistake to under-estimate the contribution radiation research has made towards our understanding of genetics and cytology.

What then can x-irradiation possibly mean to the farmer? First, because of what radiation research has demonstrated in the plant and animal kingdom, we have a sounder basis for radiation therapy and a broader concept of what radiation really does. Secondly, we have a much deeper insight into the workings of the living cell. For the farmer, the expression of this knowledge will be new and improved varieties along with a realization that, even on the farm, nuclear power can be useful.

Dr. J. M. Armstrong (left), Genetics and Plant Breeding Research Institute, examining root-tip chromosomes of an alfalfa mutant, while co-author Iris Craig is preparing buds for cytological observation.

ORCHARD WARFARE

Radiation Shows Promise Against Codling Moth

James Marshall

Spraying with a compact concentrate sprayer designed and built at the Summerland Research Station.

THERE'S no such thing as a foolproof method of controlling the more notorious orchard insects; they are just too adaptable, just too capable of modifying their behavior, and even their metabolism. As one growing season follows another in the fruit lands of British Columbia that becomes ever clearer.

To counter the orchard mites three projects have been organized at the Regional Research Station, Summerland, B.C. The first deals with short-term work on new acaricides (miticides). In this undertaking the effects of promising compounds are compared on one or more of the species of mites that are injurious in British Columbia orchards. The chief tools for this sort of work, hardly the sort of thing to fire the public imagination, are the orchard concentrate sprayer, a laboratory device known as a mite-brushing machine, and the stereomicroscope.

The second project is a long-term one concerned largely with the behavior of orchard mites, particularly the blister mites and the rust mites. All are minute species hardly visible to the naked eye. This is painstaking work in which phase-contrast microscopy plays an essential part.

Dr. Marshall is Head, Entomology Section, Regional Research Station, Summerland, B.C.

The third project, again a long-term one, has quite a different objective from the other two. It is an attempt to determine to what extent spraying practice influences the rate of development of resistance to chemicals, in orchard pests. Whether or not resistance becomes evident, is it better to vary the pesticide every year or so, or every five or ten years; or is it better to wait until resistance appears? Are low concentrations or high concentrations of insecticides the more likely to select resistant strains? Are inefficient sprayers implicated?

The pest that is used as a so-called test animal is the McDaniel spider mite. It was selected because it is a common and destructive orchard pest in British

Yesterday and Today

In the early days, the period from 1905 to 1915, insect damage was rare in British Columbia orchards, and spraying was largely confined to the application of dormant lime-sulphur with hand-operated barrel pumps. In those days many of the orchards were called "ranches" and spraying was a bit of a lark. But times have changed in the orchard, and especially so in the insect world. The trees have grown up, and provided the pests with a more favorable habitat. Since about 1930, five of the worst orchard pests—the codling moth, the pear psylla, the McDaniel mite, the European red mite, and the San Jose scale have invaded the orchards of British Columbia. The fruit growers have had to use chemicals to control the codling moth (no chemicals, no apples) and, by so doing, have favored the development of a number of other pests, particularly orchard mites. One after another the pests have been developing resistance to the very spray chemicals that saved the day in the late 'forties and early 'fifties, — chlorinated hydrocarbons such as DDT, and organic phosphates such as malathion. First it was the European red mite, then the green peach aphid, then the McDaniel mite and the two-spotted spider mite, then the codling moth; and finally, in a rash of serious outbreaks, the pear psylla. Today the battle continues.

Columbia; it can be reared readily in the laboratory on a year-round basis; it is rapidly acted upon by chemical selection; and finally, since there are no male mites of this species, the genetical aspects of selection are straightforward. Where heredity includes male as well as female the characters of the offspring have, of course, a much more complex basis.

Codling Moth Threat

Now, some comments on the British Columbia fruit growers' arch-enemy, the codling moth. Despite apparent fragility it is a real champion in the insect world. So far the codling moth has beaten man's best efforts to control it; and they have been no mean efforts. Entomologists have paid the codling moth the dubious distinction of a more voluminous literature than almost any other insect. Today, although the codling moth is actually at a low ebb in most orchards, it is, in a sense, a greater threat to apple growers in British Columbia than ever before. Why the apparent paradox?

In the first place the codling moth has not yielded to biological control; neither native nor introduced parasitic insects have had much effect on it, nor have such fungus and bacterial sprays as have been tried. Second, if conditions are favorable (hot, dry weather), the insect is capable of mounting from trace proportions to devastating numbers within two years. Consequently, its control necessitates preventive spraying. You can't delay your spraying until the codling moth is on the point of causing commercial loss; but that is just what can, and should be done with most of the other orchard pests in British Columbia. Unfortunately the spray chemicals that are at the same time effective against the codling moth and reasonable in price, e.g. DDT and Sevin, favor the increase of certain orchard mites. The mites, in turn, necessitate the use of expensive miticidal sprays. Third, the codling moth has demonstrated a pronounced capacity for survival in the face of chemical control measures no matter how effective those measures may have been when first applied.

Pear-leaf blister mites magnified about 100 times.

Between 1930 and 1945 the codling moth became so resistant to acid lead arsenate that it forced the British Columbia apple industry to the brink of ruin. In 1946 the situation was saved by the introduction of DDT. At first almost completely effective against the codling moth, but 12 years later DDT had begun to show some signs of failure. Then laboratory experiments provided the evidence; in one area the codling moth definitely had developed a high degree of resistance to DDT. Fruit growers, unable to cope with the insect with DDT, were advised to turn to molecules of a different type, the carbamate Sevin, and the organic phosphate Guthion. For the moment these are effective, although considerably more expensive than DDT. But for how long will they continue to be effective? It is suspected that the scourge of the orchard will accommodate itself to Sevin, and to Guthion, even more rapidly than it did to lead arsenate and to DDT. Unless, meanwhile, an entirely new method of control should be developed, the situation will probably force the introduction of yet other newly synthesized compounds, and the growers will continue to face the dilemma of having to use either diminishingly effective chemicals at reasonable cost, or more potent chemicals at high cost.

We are tackling the codling moth problem in three ways. The first of these has been mentioned —an attempt to find out whether spraying practice influences the development of resistance to insecticides in orchard pests. The second is more prosaic. As each promising new insecticide appears it is assessed against the codling moth in the orchard. The idea is to stock a sort of entomological arsenal for the future.

Concluded on page 16

Dr. M. D. Proverbs inserting codling moths in Gammacell Cobalt 60 irradiator.

Germinating Montcalm barley. Peeled kernels are detrimental to malt quality.

Hull Damage and Malting Barley

V. W. Bendelow

THE extent of peeling in barley intended for malting is increasing and has become a serious problem. Good quality malt cannot be made from barley with badly damaged hulls. Each year an increasing number of barley shipments fail to make the higher grades of malting barley because of the amount of peeling and hull damage. The lowest grade of malting barley permits up to 8 per cent of peeled and broken kernels. If this requirement is not met, the grade is reduced to the feed category and the value of the shipment lowered accordingly. This situation concerns both farmer and maltster. Although there has been a significant improvement in the commercial quality of Western Canadian barley in the post-war period, peeling still is a problem—one that we are studying at the Department's Research Laboratory at Winnipeg.

Why is the hull so important a factor in the quality of barley used for malting? In the manufacture of malt, barley is steeped in water until it reaches a certain moisture content and then it is germinated under controlled cool, moist conditions. Germination is allowed to proceed until the rootlets are approximately the same length as the kernel and the sprout has grown under the hull to almost its full length. The next step is a slow, controlled drying in a kiln. Barley has now become malt. It is polished (that is, the dried rootlets are rubbed off) and stored for future use. During the malting process a number of complex chemical changes occur with the result that the starch and protein substances of barley are largely converted into water-soluble materials, mainly sugars, of malt. It is important that these changes occur to the same extent in each kernel in order to produce malt of uniform composition.

Effects of Peeling

The absence of hull can have a significant effect on uniformity. Peeled kernels take up water more quickly in the steeping process and therefore their germination rate is faster. There is an even more serious effect during germination. The growing sprout, unprotected in peeled or damaged kernels, is easily broken off when the germinating grain has to be stirred. If this happens growth is interrupted and the chemical changes going on inside the kernel slow down or stop. Thus a batch of barley with a high percentage of de-hulled kernels will produce malt that is not uniform in composition.

Peeled kernels are much more susceptible to mold growth than are kernels protected by the hull. Our laboratory tests have shown mold infection on 20 to 25 per cent of malt kernels made from peeled barley compared with only 1 per cent of the malt made from sound grain. Mold growth can have several bad effects. In malting it restricts rootlet growth, adding to the non-uniformity of the product. Mold toxins that find their way into the brewing process cause unpleasant flavors and may adversely affect the yeast used for fermentation.

The functions of the hull do not cease with malting. Malt is mashed in the brewery to extract the water-soluble material. The brewer must then separate the extract solution or wort from the insoluble residue or spent grains. To do this he depends on the hull fragments from the malt to provide a filter bed. If the proportion of hull is low because of too much peeled barley being used or hull being lost in making the malt, wort filtration becomes difficult, time-consuming and therefore costly.

Lastly, malt produced from barley having damaged hulls is dark,

---

The author is a cereal chemist at the Canada Department of Agriculture Research Station, Winnipeg.

ragged and generally very unattractive. This poor appearance has considerable effect on the sale of Canadian malt on a very competitive market.

Contributory Causes of Peeling

In studying the contributory causes of peeling, our investigation showed that barley is handled at least 15 times and as many as 32 times during processing and transit, depending on where it is grown, how long it is stored and where it is processed. After threshing, barley is moved by truck to a country elevator, then by rail to a terminal elevator. It may have to be mixed in bins or, in cases of prolonged storage, moved about to several locations. From the terminal elevator barley is transferred to a ship and unloaded at a malting plant. There it is weighed, distributed to storage, then cleaned and graded and stored again. When required for malting it is elevated to the steep-tank, transferred to the germinator where during growth it has to be stirred several times, and then to the kiln. The resulting malt is polished and stored. The next move is to a brewery storage and finally to the malt mill.

Thus barley is subjected to considerable abrasive action as it is moved along augers, belts, pneumatic conveyers and other equipment, and as it is cleaned and graded. The barley hull, however, can withstand a good deal of handling provided it is perfectly sound when delivered to the country elevator. Once the hull has been even slightly damaged, peeling becomes progressively worse with each subsequent handling. There are many recent cases of barley reaching its destination with a lower grade than it received at its point of origin. The excessive peeling that occurred in transit would most likely have been avoided had the barley hull not been in a weakened condition on delivery to the country elevator. The increasing use of augers on the farm for grain handling is contributing to the peeling problem.

Current Program

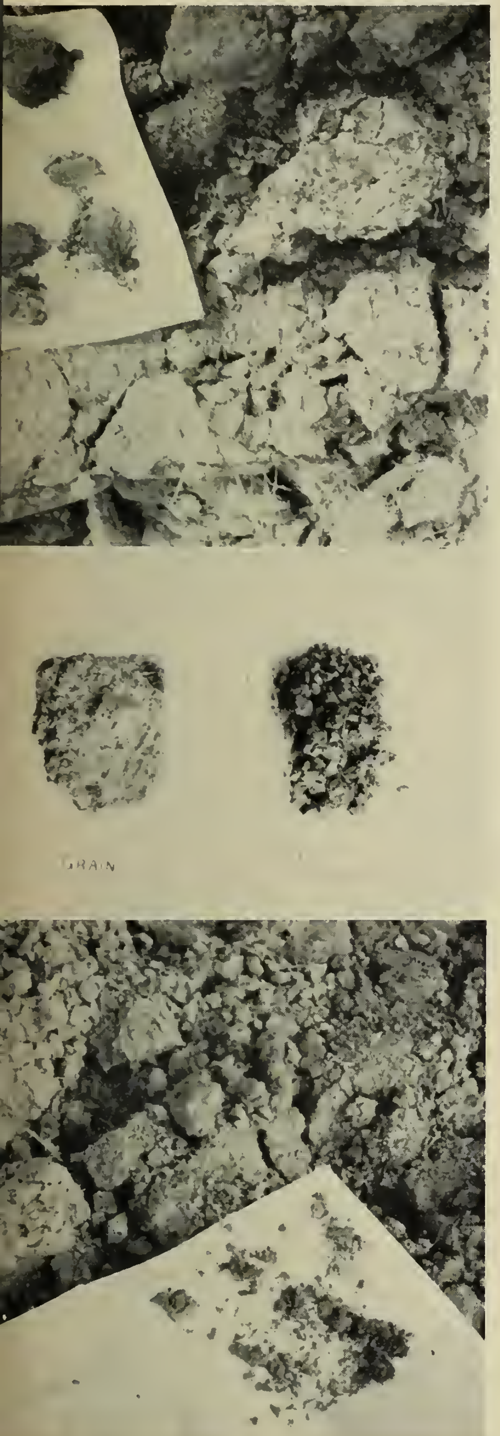
Our cereal breeding specialists have found that looseness of hull is a varietal characteristic. Since the dominant malting varieties of barley now grown in Canada lack anti-peeling characteristics, priority is being given to the production of new malting varieties with better hull adherence, and this is being approached in two ways. The hybrid lines from current barley breeding projects are being rigorously tested and only those selections with hulls resistant to damage will be retained for further development. Secondly the possibility of transferring the tight hull character of certain feed barleys to malting barleys by plant breeding is being explored.

Author doing sugar determination in malt.

The first step in the investigation of hull properties was to find a method to measure the relative susceptibility of barley samples to mechanical damage. After experiments with modified pearling machines and air blast devices, we found that a machine originally designed to de-awn barley gave the most useful results. This apparatus consists of a metal cylinder, about 2 inches in diameter and 5 inches long, which has a series of radial metal arms attached to the inside. Another set of metal arms rotates inside the cylinder on a central, motor-driven shaft. Samples of threshed barley or unthreshed heads of barley are subjected to a beating, abrasive action for a set time and the percentage de-hulling is determined by visual inspection. We have conducted a series of experiments using this technique and have established that, in addition to being a varietal characteristic, hull looseness or susceptibility to damage depends upon where the barley was grown, upon the growing conditions and upon grain moisture content. The effect of grain moisture content is clear: as the barley becomes drier, the tendency to de-hull increases. Results showed that at a moisture level of 13 per cent and higher, there was, in general, little evidence of de-hulling in most varieties. But as the moisture content was lowered to 10 per cent the susceptibility to damage became quite pronounced, more so in some varieties than in others. However, barley samples grown on irrigated plots were very loosely hulled, even when grain moisture content was high.

The investigation of barley hull properties is being continued in efforts to find out more about the hull, its nature and its relation to the kernel itself. It may take time to produce tight-hulled varieties that have all the desirable properties of existing malting barleys. Meanwhile farmers should take maximum care when harvesting barley to guard against damage.

New laboratory building for the Department's Research Station at Vancouver, B.C. to be the main center for plant virus research in Canada.



The comparative effect of cereal grain crops (top) and red clover (bottom) on the physical condition of heavy clay soil.

Red Clover 'Tops' on Heavy Clay Soils

B. K. McDonald

RED clover is the highest yielding crop grown on the heavy clay soils of Central British Columbia. These soils contain approximately 53 per cent clay and 35 per cent silt in the tillage horizon. Like other grey wooded soils they are low in organic matter and produce unstable aggregates that tend to compact and form tough surface crusts. These crusts restrict seedling emergence, reduce aeration, have low water absorption rates and when associated with a level topography, high frequency of precipitation and low evaporation, result in the accumulation of free water on the soil surface for indefinite periods of time. Approximately two-thirds of these soils are classified as Pineview Clay.

On the Experimental Farm at Prince George, we have studied the relative productivity of a number of crops commonly grown on Pineview Clay. These crops were grown in four year rotations, each of which had a common year when oats was grown in all rotations. This made it possible to measure the relative effect of these preceding crops upon the productivity and physical properties of the soil.

During the past ten years red clover has produced nearly twice as much dry matter as alsike clover and timothy. Adding timothy to the red clover had no significant effect on red clover yields during this period. Cereal grain crops are not consistently productive crops on the heavy clay grey wooded soils of Central British Columbia. Average grain yields of oats, barley and wheat were only 23, 21 and 15 per cent of the red clover yield respectively.

Pore space in the soil is essential for the storage of water, the circulation of air and penetration of the soil by plant roots. The size and distribution of the pores depends on soil structure as well as texture, a crumb-like structure being essential in fine-textured soils. To obtain such a soil condition, organic matter is needed. Since grey wooded soils are initially low in organic matter the production of cereal grain crops can result only in a deterioration of the soil condition. Yields of oats grown after the three cereal grains were quite similar as were those following timothy and alsike clover. In contrast, the oat yield increased by 70 per cent following the clover crop, indicating the beneficial effect of red clover on the productivity of these soils.

The effect of red clover on soil structure was observed soon after the first cycle of the rotation was completed. Soils growing red clover could be worked at a much higher moisture content; water and root penetration was greater, and on weathering, these soils broke down into a good granular structure. But soils growing cereal grains was easily compacted, water absorption was much reduced and on weathering, hard structureless lumps resulted.

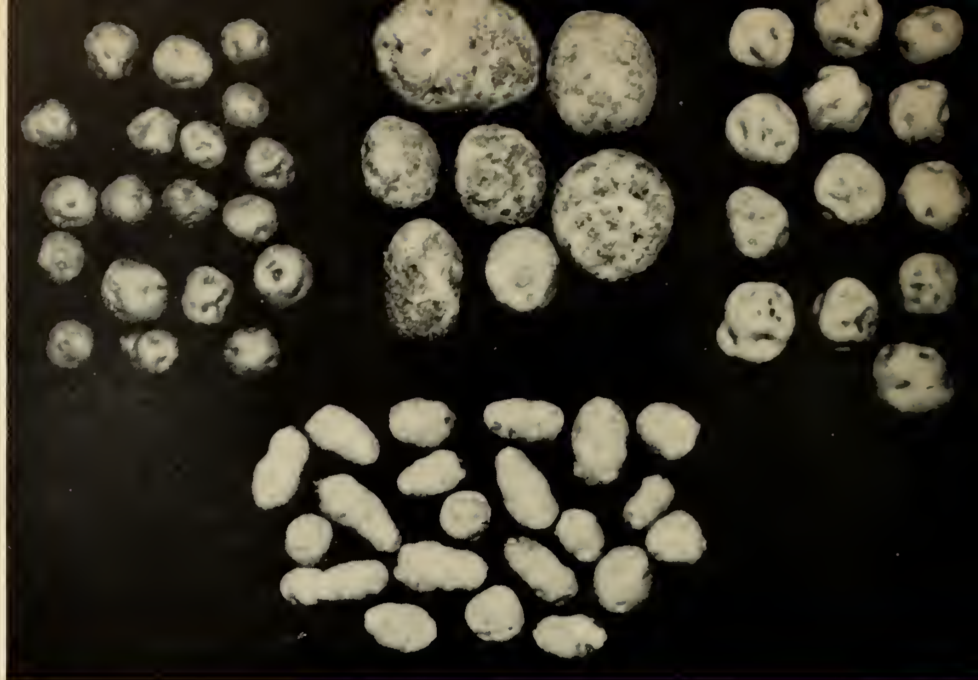
Timothy produced somewhat similar effects on the soil structure

Concluded on page 16

Mr. McDonald is a field husbandry specialist at the Experimental Farm, Prince George, B.C.

The commercial potato *Solanum tuberosum* is grown in most countries of the world. Its value as a heavy-producing crop plant is marred by its great susceptibility to insects and diseases. While these can be controlled by costly and involved procedures, the aim of many scientists has been to breed natural resistance to these pests into cultivated varieties. Late blight, common scab, and a group of highly contagious virus diseases have received special attention from potato breeders.

The wild potatoes of Mexico, Central America and South America are a veritable storehouse of disease resistance factors. The discovery of these sources of resistance has provided a great stimulus for potato breeders to breed commercial potatoes with the increased disease resistance of these wild species. The early



Potatoes grown on soil heavily infected with common scab. Large central group is from hill of susceptible variety Green Mountain. The three other groups are near-immune, extremely early derivatives of *Solanum chacoense* × *Solanum phureja*.

New Approaches to Disease Resistance From Wild Potato Species

workers who attempted to use wild species in their breeding programs soon met with disappointment. They originally conceived of crossing the wild potatoes directly with the cultivated *S. tuberosum*, then, by repeated back-crossing and selection producing varieties with the resistance of the wild parent and the economic characteristics of *S. tuberosum*. For the most part this approach has not been successful. Numerous species could not be crossed with *S. tuberosum* or if crossable their hybrids had various types of sterility that interfered with subsequent attempts at improvement. Differences in chromosome number often complicated the inheritance of disease resistance and the presence of numerous races of certain diseases confused an already difficult situation.

To overcome these impediments to the use of wild *Solanum* species in breeding programs, a co-operative project* has been under way

The author is a genetics specialist with the Department's Research Station at Fredericton, N.B.

Leo A. Dionne

in Fredericton involving a biochemist, a cytogeneticist, and four pathologists. This work represents one phase of the National Potato Breeding Program. The object of the project is to determine why *Solanum* species cannot be intercrossed; to find methods for overcoming the barriers to crossability; to produce fertile disease resistant parental material and to determine how disease resistance is inherited in the derivatives of the various wild species.

The basic chromosome number of the genus *Solanum* is twelve. The tuber-bearing species vary in their chromosome number from

*The co-operating officers are all on the staff of the Canada Department of Agriculture Research Station in Fredericton, New Brunswick. They are: L. A. Dionne, Cytogeneticist; K. Graham, Pathologist (specialist on races of *Phytophthora infestans*); W. A. Hodgson, Pathologist (specialist on the mechanisms of resistance to *P. infestans*); C. H. Lawrence, Pathologist (specialist on *Streptomyces scabies*); J. W. McAllan, Biochemist; J. Munro, Pathologist (specialist on potato viruses).

diploids with two sets of chromosomes (2n=24) to hexaploids with six sets (2n=72). The commercial potato is a tetraploid (2n=48).

Our work with the Mexican hexaploid *S. demissum* will serve to illustrate how basic difficulties are circumvented. *Solanum demissum* has been widely used by potato breeders as a source of resistance to the late blight organism *Phytophthora infestans*. However, potato varieties bred from this species have inherited only a part of the blight resistance of their wild ancestor. The work in Fredericton has shown that this loss of resistance is due to recessive and incompletely dominant factors that are eliminated in the process of back-crossing the hybrids to *S. tuberosum* to improve their horticultural characteristics. Theoretically, the loss of these factors could be prevented by alternating the back-crossing program with inter-crossing of the hybrids. Since the *S. demissum* × *S. tuberosum* derivatives are universally male sterile, inter-crossing

Concluded on page 16

As many as 25 eastern field wireworms have been found feeding on one plant of corn, tomato, tobacco, and cabbage.

In Southwestern Ontario . . .

Wireworm Controls Pay Off

Chatham Entomology Laboratory Maintaining Watch on Seasonal Abundance to Detect Any Evidence of Resistance to the Insecticides Now in Use

J. A. Begg

THERE has been a major change in the status of wireworms in southwestern Ontario during the last 10 years. Continued use of control measures developed by the Entomology Laboratory, Chatham, Ont., has reduced most infestations to non-economic levels. Few cases of injury to any crop have been reported since about 1957. Before that, wireworms had been a limiting factor in the production of susceptible crops. It was not unusual for entire fields of tobacco, tomatoes, cabbage, sugar beets, and corn to be replanted two and three times before a satisfactory stand could be obtained. In many districts, potatoes could not be grown at all.

The crop loss caused by wireworms in the sandy soils of southwestern Ontario has, almost without exception, been attributed to the eastern field wireworm. The intensive cultivation practiced in this area favors this species since the females prefer to lay their eggs in loose cultivated soil. Infestations gradually increased over a period of years until many crops could only be grown with difficulty. No progress was made in control until synthetic organic insecticides were introduced. These materials, which kill by contact action, offered the first means of preventing damage. Between 1948 and 1954, investigations at the Chatham Laboratory showed that the eastern field wireworm could be safely and economically controlled with seed, planting-water, and broadcast soil treatments. Life-history studies indicated that these measures would consistently give good control.

The author is a wireworm and cutworm specialist with the Department's Entomology Laboratory, Chatham, Ont.

Seed Treatments

Treating the seed of large-seeded crops with the wettable powders of various chlorinated hydrocarbon insecticides offers an easy and economical method of controlling wireworms. It is incredible that the very small amount of insecticide that adheres to a seed provides a high degree of protection. Apparently, the treatment repels as well as kills the wireworms because the reduction in numbers of larvae in treated plots have never been greater than 25 per cent. Infestations, however, are progressively reduced by continued use of seed treatments. All the sugar beet seed and the greater percentage of the corn seed planted in southwestern Ontario are treated annually for the control of wireworms.

Aldrin, dieldrin, heptachlor, and lindane were recommended at the rate of 1 oz. of toxicant per bushel of cereal or corn seed until 1958 when the dosage was reduced by one-half. This rate is adequate against the reduced population of wireworms. The Ontario recommendation now parallels that in western Canada, which is based on 1 oz. of insecticide to the amount of cereal seed required to plant one acre.

Seed treatments are particularly effective against the eastern field wireworm which generally attacks only the seed and root system. This method of control occasionally has failed to prevent attack by other species of wireworms which, under certain conditions of soil moisture, feed on the stem above the treated seed.

Planting-water Treatments

The success obtained with seed treatments in southwestern Ontario naturally suggested that transplanted crops could be similarly protected from wireworm attack by treating the transplanting water with an insecticide. Experimental work showed that ¼ oz. of lindane per 40-gallon barrel of water would satisfactorily control wireworms attacking tobacco, tomato, and cabbage with no adverse effect on growth or flavor. Wettable powders of aldrin, dieldrin, or heptachlor were also found to be effective, but generally were inferior to lindane when ap-

plied for control of heavy concentrations of wireworms. For many years now, the addition of a small amount of insecticide to the transplanting water has been a recognized operation in growing transplanted crops in certain districts.

Planting-water treatments consistently control the eastern field wireworm because it seldom attacks the undergound stem above the level of the treated soil. In the United States, this method fails to prevent feeding damage by certain very active species of wireworms which attack the stem just beneath the soil surface.

Broadcast Soil Treatments

The high degree of control required to protect potatoes and other highly susceptible crops from wireworm attack can be obtained only by killing the wireworms. Potatoes, in contrast to seed and transplanted crops, are subject to injury throughout the growing season. The larvae feed on the seed pieces, but also tunnel in the new tubers rendering them unmarketable. Treating the soil with a contact insecticide generally provides immediate control and prevents re-infestation for three years and longer.

BHC was the first soil insecticide used for eradicating wireworms in this area. From 1948 to 1951, the pungent odor of this material was very noticeable in the spring in tobacco-growing districts. BHC, however, was not the ideal insecticide for controlling wireworms. It was disagreeable to apply, and for at least two years after application potatoes grown in treated soil were tainted.

Investigations were continued at Chatham to devise a more practical method of control. This work resulted in the development of soil treatments that may be used on potato land with no adverse effect on tuber quality. Chemical analyses, insect bioassays, and mammalian feeding trials made on potatoes grown in treated soil indicated that insecticide residues should not constitute a threat to the health of the consumer.

When applied at 5 lb. per acre for control of an exceedingly heavy population of wireworms, dieldrin and aldrin prevented re-infestation for at least three years, and chlordane for two years. Only dieldrin satisfactorily protected potatoes in the year of application. Against a moderate population of wireworms, aldrin at 3 lb. per acre also provided effective control in the same year. These results indicated that soil treatments should be applied in the year preceding a potato crop. Apparently some time is required for wireworms to come in contact with a lethal concentration, since insecticides are not mixed evenly in the soil by standard cultural practices.

Since 1955, most of the potato land in southwestern Ontario has been treated with aldrin at 3-5 lb., chlordane at 5-8 lb. or dieldrin at $2\frac{1}{2}$ to 5 lb. per acre. The lower rate of application is used in the year preceding the potato crop, or for control of small populations of wireworms. This practice has resulted in marked improvement in tuber quality, and wireworm damage is now the exception rather than the rule.

Soil treatments may be applied with either crop sprayers, broadcast equipment, or fertilizer drills in the form of sprays, granulated formulations, or insecticide-fertilizer mixtures. Immediately following surface treatments, the insecticide should be worked into the soil to a depth of 4 to 6 inches. No further cultural operation is required when a treatment is drilled beneath the soil surface.

Re-infestation of treated fields is adversely affected by the life-history and habits of the eastern field wireworm. The larval period is from three to five years, and females fly only short distances until most of their complement of eggs has been deposited in the field in which they developed. It has been observed that re-infestation of large treated fields has been much slower than in small experimental plots. The wireworm population is still practically nil in one field treated with BHC in 1948. There has been no evidence of population increases in potato fields treated since 1955. This suggests that no resistance to insecticides in current use has developed to date.

Scenes of the past. *Left:* This field of corn had been replanted twice because of wireworms. *Right:* Wireworm injury in flue-cured tobacco; untreated plot in foreground, treated plot in background.

Chlorotic leaf symptoms caused by natural infections with barley yellow dwarf virus on compana barley . . .

. . . on Clintland oats

. . . on spring wheat.

Barley Yellow Dwarf

A Common Disease of Cereals

J. T. Slykhuis

THE aphid-transmitted barley yellow dwarf virus (BYDV) is the most widely distributed of the viruses known to affect cereal crops. First recognized in 1951, it has since been found in most cereal growing areas of Canada and the U.S.A. and in many other countries.

The virus and the role of aphids as vectors were first recognized in California in 1951 when widespread yellowing, stunting and yield losses occurred in barley, especially in late sown crops. Similar symptoms on wheat, and a reddening often called "red leaf" of oats were attributed to the same cause. Rye and a large number of annual and perennial grasses were also infected but less readily than barley, oats and wheat.

We now realize that BYDV has been present for many years, and probably infected cereals as long as they have been grown in North America. It probably caused some of the severe damage in oats, barley and wheat attributed in former years to insect damage, mineral deficiencies or excesses, and other infectious diseases. Pathologists in the United States believe it to be the most destructive disease affecting oats in that country. Although no estimates have been made of losses in Canada, we found the virus in plants collected on the prairies, and in Ontario, Quebec and New Brunswick. Characteristic symptoms have been recognized on cereals and grasses from British Columbia to Prince Edward Island. In 1958, about 15 per cent of the oats and barley in the Ottawa valley showed symptoms of the disease by mid-July. Only one to five per cent showed symptoms at the same stage in the same area in 1959, but heavily infected crops that would bring reduced yields were observed in other areas. The virus probably infects a small percentage of plants in all areas each year. Under favorable conditions severe damage results, but commonly the infections are so light or so late that visual symptoms are not evident. At Ottawa we are attempting to learn from where the first disease-carrying aphids come each season, and to find out how to avoid serious infections in cereal crops.

Dr. Slykhuis is Head, Phytopathology Section, Plant Research Institute, Ottawa.

Symptoms and Effects Vary

The symptoms of BYDV vary considerably with strain of virus, species, variety and age of plant, and the environmental conditions after infection. Yellowing and stunting are the most common field symptoms. On barley and wheat the yellowing of leaves usually progresses downward, at first principally along the leaf margins, but eventually the entire leaf becomes golden yellow. Sometimes young leaves show a longitudinal yellow and green striping. In some varieties yellowing occurs in blotches which enlarge and the leaves eventually become totally yellow. Usually the leaves of diseased plants are stiffer and more erect than normal. Stunting is most severe in plants infected in the one- to four-leaf stage. Tillering may be increased but internode elongation is reduced or inhibited and the plants may never develop heads. Despite this, some leaves may grow to a limited extent, and are often twisted, crinkled and serrated from breaks along the edge. The roots of diseased plants are usually as severely stunted as the tops, hence such plants die quickly during hot dry weather. Plants not infected

until later are less severely stunted and may produce heads with few and light kernels. Late infection may show only as a bright yellowing of upper leaves, particularly the flag leaf. Symptoms on oats are generally like those described for barley and wheat, except for the reddish coloring of some affected leaves.

Yield losses are probably greatest in oats, but barley and wheat can also suffer severe losses if they are infected when young. In our field experiments at Ottawa in 1958, virus-carrying aphids that fed for a few days on Clintland oats, Garry oats and Montcalm barley in the 3-4 leaf stage, reduced yields 75.3, 77.6 and 53.5 per cent. Infection two weeks later reduced yields 56.1, 59.7 and 23 per cent, but plants infected at the jointing stage suffered no measurable yield losses.

Virus Harbored in Grasses

Perennial grasses seldom show distinctive symptoms of yellow dwarf, and diseased plants are difficult to spot in solid or mixed stands of grass. Sometimes we have noticed stunted, slightly chlorotic plants in spaced plantings and have isolated BYDV from some of these. Some perennial grasses are symptomless carriers. Grasses found naturally infected in the Ottawa area include timothy, brome grass, Kentucky blue grass, perennial rye grass, creeping red fescue and intermediate wheat grass. No estimates have been made of the probable effects of BYDV on grass yields, but some of the losses in vigor of old stands may have resulted from infection. However, cerealists are more interested in the role of perennial grasses as reservoirs of the virus, and in some areas as overwintering hosts of aphid vectors.

Spread by Aphids

No discussion of BYDV would be realistic if it did not emphasize the importance of the aphids that carry the virus. The basic procedures for testing aphids as vectors are simple. The aphids are fed on leaves of diseased plants for about two days, then put on young plants of a susceptible variety, usually oats, for another two days. The aphids are then removed and the test plants incubated in a greenhouse at about 70°F. with ample light. Infected plants begin to show symptoms in 10-15 days. At least 9 aphid species names have been associated with transmission of BYDV, but in some cases more than one name has been used for what is essentially one species of aphid.

The names *Rhopalosiphum prunifoliae, R. fitchii and R. padi* probably all refer to the same species, commonly called "apple grain aphid". Similarly *Macrosiphum granarium* and *M. avenae* are probably the same "English grain aphid". Other aphids, generally considered as poor vectors, include the grain aphid or green bug, (*Texoptera graminum*), the grass aphid (*Macrosiphum dirrhodum*), the cornleaf aphid (*Rhopalosiphum maidis*) and the blue grass aphid (*R. poae*).

Clintland oats in 2-leaf stage on which aphids (*Rhopalosiphum padi*) had fed for 2 days; aphids were non-viruliferous (left), carried a moderate strain of BYDV (center), and severe strain (right).

Few if any of the various strains of virus can be transmitted by all of the above-mentioned aphids which have been proved vectors. The apple grain aphid is an efficient vector of strains of virus not readily transmitted by the English grain aphid, yet it fails or transmits poorly other strains that are very efficiently transmitted by the English grain aphid. Still other strains of virus have been transmitted more readily by the corn leaf aphid than by any other. Some strains of the green bug transmit some strains of BYDV with a high efficiency.

The existence of vector-specific strains of the virus raises important questions. If one aphid species infects cereal plants early in the season with strains transmissible only by that vector, other species could not likely spread the virus from those plants. An understanding of the life history of each species of vector is therefore necessary to understand the epidemiology of various strains of the virus.

Control Promising

A measure of control of BYDV can be achieved by planting spring grains early. This is important because aphids generally become more common as spring and summer progress, and early-sown crops may escape aphid infestations while still very young and most susceptible to severe damage from virus infections. Some of the viruliferous aphids entering spring grains may originate from local overwintering aphids or eggs, and may acquire virus from local perennial grasses. Also, viruliferous aphids may be blown in from great distances. Studies of such factors are basic to improvements in cultural and other forms of control.

Disappointing results have been obtained with most tests to control BYDV with insecticides, but in one instance, spectacular control resulted from the use of one application of a systemic insecticide, Dimethoate. This chemical is being widely tested in Canada and the United States.

Differences in varietal susceptibility were evident from the time BYDV was first recognized, but some varieties tolerant to one strain may prove susceptible to other strains of the virus transmitted by the same vector. Further differences may be expected in the reaction of strains of virus transmitted by different aphids. In 1959, several varieties of oats and barley showed moderate resistance to BYDV in the field in several areas of U.S.A., and Canada but it is still not known if they would be tolerant to all strains of virus that may be spread by the various vectors that may predominate one season or another.

Sagebrush, which has become a weed on B.C.'s interior range land because it crowds out and suppresses native forage plants, is being eliminated by a chrysomelid beetle (inset) that defoliates the plant. Note growth of range grasses due to bush-kill.

Beneficial Beetles

Study Reveals 50% Kill of Sagebrush

W. L. Pringle AND *D. A. Arnott*

Not all insects are bad. Certain insects benefit mankind either by preying on harmful species or by consuming and controlling weedy plants. This appears to be happening near Kamloops, in the dry southern interior of British Columbia, where a chrysomelid beetle, *Trirhabda pilosa* Blake, has attacked big sagebrush, *Artemisia tridentata* Nutt.

Big sagebrush, a perennial shrub, is native to the lower grasslands of the interior valleys and is one of the main plant components from the 1000 to 2000 foot level in the light brown soil zone. This shrub, however, invades many grasslands above this zone where there is more effective moisture and where excessive grazing or futile attempts at dry farming have aided its entry. Under such conditions the sage stands are exceptionally vigorous, the plants attaining a greater size than on the lower grassland. The sagebrush becomes a weed because it crowds out and suppresses the native forage plants of the range. Thus any natural force that might destroy this plant can be looked on with favor.

The insect is a native beetle about one-quarter inch long by one-eighth inch wide; dull green in color and with gray stripes along the outer edges of the upper wings. It feeds only on sagebrush. It has one generation a year and overwinters in the egg stage. Eggs are deposited in debris on the ground surface below the host plants. Hatching occurs from late May through June. Newly hatched larvae crawl up the bushes to the tips of branches where they feed on the tender leaf growth, moving downward as the foliage is consumed. Mature larvae are about one-half inch long, bluish-black in color, with a metallic lustre. Both adults and larvae feed on foliage but the greatest amount of defoliation is done by the larvae. Peak larval feeding occurs through June and early July. The larvae, when full grown, move down to the ground below the bushes and pupate among the debris on the ground surface or at shallow depths in the soil. The pupal stage lasts one to two weeks. Adults emerge during July and August. When the adults emerge from below the damaged shrubs they tend to move to healthy, uninfested plants where they lay eggs during August and September and a new infestation is thus established.

In 1954 we found larvae of this beetle infesting about two acres in an extensive stand of sagebrush on a range at 3000 feet elevation. The insects spread from this small area throughout a large part of the sagebrush stand. By 1958 the beetles were observed five miles distant from the original infestation. Already much of the sagebrush in an area of over 4000 acres has been seriously affected and local infestations are still active.

In the infested areas we made study of the changes in plant cover. Where defoliation was severe, fifty per cent of the shrubs were killed in one season. Other plants were so defoliated that they offered little competition to native grasses. Some bushes regained normal growth after the wave of insects had passed on. Larger plants used as aphid pasture by ants were not attacked and many small plants did not appear to be attractive to the beetles.

Although the beetles have not completely eliminated sagebrush from infested stands, the heavier infestations have thinned the growth to such an extent that growth of forage grasses has increased. Whether the beetle infestations will remain and be effective in killing sagebrush is conjectural. The possibility of using the beetle for biological control of sagebrush might be considered in a program of range management but will require further research.

Mr. Pringle is the Agronomist at the Experimental Farm and Mr. Arnott is an Entomologist at the Entomology Laboratory, Kamloops, B.C.

Orchard Warfare . . . from page 6

Radiation Holds Promise

The third approach, and one that appeals to the popular imagination, was made possible by recent developments in radiation technique. For the last four and a half years an experiment has been under way at Summerland with the object of controlling the codling moth by the mass liberation of active, but sexually sterile, male codling moths. By exposure to gamma radiation from a cobalt "bomb" somewhat similar to that used in cancer therapy, but much more powerful (a radiation dosage that might kill a human male has no observable effect, sexually or otherwise, on the codling moth male), the insects are sterilized just before they emerge from the pupal case as adults. The theory behind this approach is that if an insect is present in trace proportions only, as the codling moth is in most orchards, and if its mating habits are conducive to the control procedure, it is mathematically possible not only to control, but to eradicate the insect by several successive releases of sexually sterile males. At each release their numbers should exceed those of the wild, or sexually potent, males that were originally present by about ten to one.

The point is, that if a fertile female moth looks favorably on a sterile male moth before she encounters a fertile male, she will lay her full complement of eggs; but they won't hatch. And if all the female moths in an area start off with a ten to one chance of a sterile mating and if that chance becomes greater with each generation, the species will perish within a few years.

The technique has proved successful on the island of Curaçao where United States entomologists have eradicated the screwworm, a serious pest of domestic animals. The chief significance of this accomplishment is that, in the control of insects, eradication has nearly always been an unattainable goal. Only time, and a lot more work, will show if the codling moth can be dealt with as successfully as the screwworm. Should that prove to be so, there will be no codling moth sprays, and almost equally important, few, if any, mite sprays. This is a fairly long chance. But the stakes are high in the orchard war, and even fairly long chances are not hard to justify.

Red Clover 'Tops' on Heavy Clay Soils . . . from page 9

but these beneficial effects were not reflected in succeeding oat crop yields. The oat crop was not fertilized even though nitrogen is in extremely short supply in the soils of Central British Columbia. This would explain why oat yields following timothy were considerably less than those following red clover, even though the physical condition of the soil was similar in both cases.

During the past year we made laboratory analyses of soil samples, so that physical differences due to the crop grown might be classified. Pore space, organic-matter content and field moisture-holding capacity were improved where either red clover or timothy were grown. The work of measuring soil physical differences as they affect soil productivity is being continued. Meanwhile, two points have been established: 1. The physical condition and productivity of grey wooded clay soils deteriorate quite quickly under cereal grain production. 2. Red clover has been the most productive crop grown on such clay soils in Central British Columbia.

New Approaches to Disease Resistance from Wild Potato Species . . . from page 10

is not possible. We have demonstrated that male sterility is due to the interaction of cytoplasmic (non-nuclear) factors from *S. demissum* with nuclear factors from the *S. tuberosum* parent. Male sterility could be eliminated by reversing the direction of the original cross but *S. demissum* will only cross with *S. tuberosum* when used as a female parent. However, *S. demissum* can be crossed as a male parent with some close diploid relatives of *S. tuberosum*. The resultant hybrids can be self-pollinated and inter-crossed and their hybrids with *S. tuberosum* are quite functional as male parents. By means of such hybrids new and higher levels of blight resistance have been obtained, including some that are apparently resistant (but not immune) to all races of the late blight organism.

Similar obstacles to the use of *Solanum stoloniferum*, another Mexican species with forms that are apparently immune to all races of late blight and others immune to a serious virus disease were eliminated by a procedure similar to that used with *S. demissum*.

Extremely early derivatives of *Solanum chacoense* (a diploid species from South America) have been obtained that have near immunity to common scab and that cross readily with *S. tuberosum*. Unfortunately, these have inherited a bitter principle from their wild ancestor but we expect to eliminate this in the near future.

A group of Mexican species is known to be immune to all races of late blight but this group of species has completely refused to cross with *S. tuberosum*. Study of the isolation mechanism of these species has indicated how hybrids may be obtained. The first such hybrid is now growing in our greenhouse.

Intensive work along these lines has only been underway for about three years but already the results have been most encouraging. It appears likely that this and similar work going on elsewhere will open up the vast reservoir of disease resistance factors present in the wild *Solanum* species This could allow the potato to fulfil its potentialities as a nearly universal crop that can contribute greatly toward feeding the exploding population of a hungry world

Roger Duhamel, F.R.S.C., Queen's Printer and Controller of Stationery, Ottawa, 1960